KUTCH POWER GENERATION LIMITED, 5 x 660 MW COAL BASED THERMAL POWER PROJECT AT VILLAGE BHADRESWAR, MUNDRA TALUKA, KUTCH DIST, GUJARAT

REPORT ON MATHEMATICAL / HYDRAULIC MODELLING STUDIES ON HOT WATER RECIRCULATION AND SEDIMENT TRANSPORT FOR CW INTAKE AND OUTFALL DISCHARGE SYSTEM

For

Kutch Power Generation Limited.

Ahmedabad

Draft Report

July 2010

By

Environ Software (P) Ltd
Bangalore

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EXECUTIVE SUMMARY

The findings of the studies details in the report are summarized below.

Hot water recirculation studies

Under various hydrological, oceanographic and meteorological conditions in the Gulf, the basic oceanographic filed data pertaining to tides and tidal currents have been made available for carrying out the modeling studies. Hydrodyn-POLSOFT, developed at Environ Software (P) Ltd. has been used for predicting the tides, tidal currents and dispersion parameters in the model .The model has been run with the available data of tide for various tidal conditions to predict the effects due to intake and outfall discharges on the thermal dispersion processes. Model results show that ambient temperature conditions are arrived within the Land Fall Point (LFP) of intake channel. From the flow modeling studies it can be concluded that the proposed intake and the outfall locations are suitable for all the tide conditions and the proposed outfall discharge. The software POLSOFT has been run for 25 days continuously to calculate the dispersion patterns for various flow conditions. Results of POLSOFT shows that there is no hot water recirculation between the outfall and intake channels and no significant impact on the marine life due to the proposed outfall discharge.

PROJECT TEAM OF ENVIRON SOFTWARE (P) LTD

G. S Reddy	Managing Director
Lavanya M	Member
Girish V	Member

RESOURCE PERSONS OF KPGL, AHMEDABAD

Mr. Manoj Deshmukh	Project Leader

1. Introduction

A formal assessment of power plant effluents dispersion and sediment transport processes taking place with respect to the prevailing environmental conditions such as, flow regime, wave climate, wind effects etc. in the open waters of Bhadreswar region, Gulf of Kutch plays important role in the finalizing the designs of CW intake and discharge system of Kutch Power Generation Limited (KPGL) (5x660 MW) The report presents the studies on thermal discharge CW and recirculation, salinity dispersion and sediment transport in the region of proposed intake and outfall locations. The proposed locations of the intake and outfall of the CW system as shown in Fig.1. The intake channel of 100m width and 600 m long from LFP will run up to (-) 3 m depth contour at LTL. The proposed effluent is d*ischarged through channel from power plant to LFP point on the land and then through the dredged channel for about 600m to -1m depth with a designed for desired dispersion*

1.1 Back ground

Kutch Power Generation Limited is proposing to set up 3300 (5X660) MW Coal-based Super-critical (Open Cycle) Thermal Power Plant at Village-Bhadreswar, Taluka-Mundra, Kutch District, Gujarat. Because of high generation capacity, the proposed project will meet the power demand of a number of states through transmission of power on regional and national basis.

The KPGL's 5x660 MW power plant is proposed in the Bhadreswar based on once-through Cooling Water (CW) system. The sea water propose to inlet channel with a capacity of approximately 525000 m3/hr. The power plant will return the intake water to the open water through discharge channel with chemical composition unchanged, with a temperature increase of 4.5 ^{0}C and salinity will increase of 4 ppt. Hence, there is a need to identify a suitable location for outfall in the Bhadreswar region, Gulf of Kutch without any hot water recirculation problem and cost effective for implementation. A careful assessment of quantum of sediment transport expected in the region of development also assumes significant importance in the design of the CW system.

1.2 Gulf of Kutch

The coastal environment off Mundra forms an integral part of Gulf. Hence, the knowledge of the general ecology of the Gulf is necessary to understand the site-specific environmental conditions with that of the parent body.

The Gulf which occupies an area of 7300 Km^2 (Fig. 1) has maximum depth that varies from 20 m at the head (Kandla – Navalakhi) to 60 m in the central regions. The actual waterway however is obstructed due to the presence of several shoals, needing periodic dredging in some areas, to facilitate navigation to Kandla port. The tidal scour which follows the axis of the Gulf has steep slopes and rugged surfaces. A number of scraps with relative elevation of 6 to 32 m occur on the sediment-free bed on the central Gulf.

All along the coast, very few rivers drain into the Gulf and they carry only a small quantity of freshwater, except during brief monsoon. They are broad-valleyed and the river beds are mostly composed of coarse sand and gravel. The Gulf is characterised by numerous hydrographic irregularities like pinnacles, as much as 10 m high. The southern shore has numerous islands and inlets covered with mangroves and surrounded by coral reefs. The northern shore is predominantly sandy or muddy confronted by numerous shoals.

The coastal configuration is very irregular with numerous islands, creeks and bays. Besides, there are a number of eroded shallow banks like Pirotan, Dide, Dhani, Paga, Adatra reefs along the southern shore, many of which harbour living corals. The intertidal region is sandy, muddy or rocky.

Tides in the Gulf are of mixed, predominantly semidiurnal type with a large diurnal inequality. The tidal front enters the Gulf from the west and due to shallow inner regions and narrowing cross-sections, the tidal amplitude increases considerably, upstream of Sikka. Due to these high tidal ranges in the inner regions, the vast mudflats and coastal low lands which get submerged during the high tide are fully exposed during low tide.

The circulation in the Gulf is mainly controlled by the tidal flows and bathymetry though wind effect also prevails some extent. The maximum surface currents are moderate (0.7-1.2 m/s) but increases considerably (2.0-2.5m/s) in the central portion of the Gulf. The spring currents are 60 to 65% stronger than the neap currents. The bottom currents are also periodic with a velocity normally 70% of the surface currents.

With high tidal range, negligible land run-off and irregularities in topography, the waters are vertically homogeneous in terms of salinity and temperature.

Central portion of the gulf extending from the mouth to upstream of Sikka is rocky with sediment confined only to the margins. The near shore sediment, which consists of light gray silt and clay and fine sand with patches of coarse sand in between, are poorly sorted with highly variable skewness. The major source of this sediment is considered to be the shore material and the load transported by the Indus river.

1.3 Meteological, oceanographical features of selected site

1.3.1 Rainfall and Temperature

The Kutch is a semi-arid region with weak and erratic rainfall confined largely to June-October period. With a few rainfall days, the climate is hot and humid from April till October and pleasant during brief winter from December to February. Although the monthly mean maximum temperature recorded is 37^{o}C during 2005, it occasionally exceeds 40^{o}C. Rainfall alone forms the ultimate source of freshwater resource to the region.

1.3.2 Cyclones

Cyclonic disturbances strike North-Gujarat, particularly the Kutch and Saurashtra regions, periodically. These disturbances generally originate over the Arabian Sea and sometimes the Bay of Bengal. Generally during June, the storms are confined to the area north of 15^{o}N and east of 65^{o}E. In August, the initial stages, they move along the northwest course and show a large latitudinal scatter. West of 80^{o}E, the tracks tend to curve towards north. During October the direction of movement of a storm is to the west in the Arabian Sea. However, east of 70E some of the storms move north-northwest and later recurves northeast to strike Gujarat-north Mekran coast.

1.3.3 Wind

In the period lasting over months March to May the wind direction is generally SWW (225˚ - 250˚) and velocity varies from 10.28 m/sec 12.75 m/sec. June through August the wind direction is predominantly SW and velocity varies from 25 to 30 Knots with short gusts going up to 17.99 m/sec to 20.56m/sec. Towards end of September and through October wind direction changes to NE with velocities ranging from 3.6 m/sec to 5.14 m/sec. Direction remaining same the velocity varies 5.14 m/sec to 12.85 m/sec in the period November to January. February is the calm period when wind direction is southerly with velocity in the range of 3.6 m/sec. Stormy weather may generate winds having velocity up to 51.4 m/sec which should be taken as the worst case scenario for design of tall structures and heavy duty cranes.

1.3.4 Tides

The tide levels at Bhadreswar were assessed in 1998 as shown in Table below

Table

Tide	Height (m) above CD
Highest High Water level	6.4
Mean High Water Springs	5.8
Mean High Water Neaps	4.6
Mean Low Water Neaps	2.1
Mean Low Water Springs	1.0
Lowest Low Water Levels	0.0

The Highest Astronomical Tide (HAT) is estimated to be about +6.4 m above chart datum (CD), and the Lowest Astronomical Tide (LAT) to be at 0.0 m CD.

1.3.5 Tidal Currents

It is observed from the available information data show that the flood currents are to that east (80-90 N) and the ebb currents are to the west (270N-280N). The magnitude of tidal currents in the area under spring and Neap tides varies between 0.47 m/sec to 0.77 m/sec.

1.3.6 Waves

It is observed from the available information data that the wave climate considering wave energy from locally generated waves and swell propagating in to the Gulf of Kutch from the Arabian Sea during the monsoon period viz. August 2007 to September 2007. The results of the observations carried out indicates that wave height varties between 0.34 m amd 1.47 m with corresponding wave period between 6 sec and 6.4 sec.

2. Proposed cooling water intake and outfall system

The KPGL is coming up in the Bhadreswar region and the power plant capacity is of 5 x 660 MW. The power plant is proposed on indirect cooling system with the use of cooling towers. The proposed power plant requires 5,25,000 m3/hr sea water for their process and cooling requirements.

The proposed locations of the intake and outfall of the CW system as shown in Fig.1. The intake channel of 100m width and 600m length from LFP and will run up to (-) 3.0 m depth contour at LTL. The effluent discharge is discharged through channel from power plant to LFP on the land and then through the dredged channel for about 700m to -1m depth with a designed outlet structure for desired dispersion.

A inlet channel with a capacity of approximately 5,25,000 m3/hr has proposed for drawing intake water for cooling and boiler feed purposes.

Discharge of rejects

The discharges from the KPGLs power plant will be higher in salinity and temperature and the water will get hotter due to heat exchange in the cooling tower. Similarly the discharge from the desalination plant will be high in salinity.

It is proposed to discharges from proposed KPGL's power plant and desalination plant collectively in a channel proposed to be disposed through channel (5,00,000 m3/hr) at 3m CD contour 700m LFP.

3. SCOPE OF STUDY

Kutch Power Generation Limited, Bhadreswar, requested Environ Software (P) Ltd, to carry out the mathematical modeling studies on hot water recirculation and sediment transport with the proposed intake and outfall locations of KPGL of 3300MW capacity (5x660MW) at Bhadreswar, Kutch district, Gujarat.

Objectives

The following are the main objectives of the present study.

1. **Hydrodynamic studies**
   - Simulate the flow conditions prevailing at the site based on the bathymetry, and tidal conditions.
   - Predict the flow conditions at site considering the withdrawal from the proposed intake channel and discharges from the outfall at proposed location for following for spring and neap tidal conditions;
   - Intake channel is at 3m CD and Outfall channel discharging at 1m CD

2. **Sediment transport Studies**
   - Modeling of sediment transport processes under various tidal conditions considering withdrawal from Intake and discharge from outfall channels Predict siltation pattern and estimate the quantum of sediment expected in channels and requirement of de-silting over the year during the monsoon and post monsoon period. Establish the requirement or otherwise of bund (on one side or both sides of channel) including height of bund based on sedimentation at site.

3. **Thermal and Salinity dispersion studies**
   - Thermal & salinity modeling to study the dispersion of effluent and to confirm the intake/outfall locations from recirculation considerations
   - Study of various alternatives (Channel/Pipe line)to be carried out and to arrive at an appropriate scheme for the discharge of the effluent
   - Predicting the salinity and temperature variations at the proposed outfall location during pre-monsoon and post monsoon seasons

4. Site conditions

Kutch Power Generation Limited is proposing to set up 3300 (5X660) MW Coal-based Super-critical (Open Cycle) Thermal Power Plant at **Village-Bhadreswar, Taluka-Mundra, Kutch District, Gujarat.** Because of high generation capacity, the proposed project will meet the power demand of a number of states through transmission of power on regional and national basis. The station locations considered for the study are illustrated in Figure 1

The site is located at Latitude **22° 53’ 18.4" North** and Longitude **69° 52' 01.6" East** Coordinates in **Village-Bhadreswar, Taluka-Mundra, Kutch District, Gujarat.** The details of the location are given in Table 2.1.

Table 2.1 Location of the Project Site

Location	**Village:** Bhadreswar **Taluka:** Mundra **District:** Kutch **State:** Gujarat
Latitude	**22°53’18.4”N**
Longitude	**69°52’01.6”E**
Nearest Railway Station	Anjar (20 kms) & Gandhidham (35 kms)
Road Connectivity	8 km from NH-8A
Nearest Water Body	2.0 Km (Mithi River)
Site Contour	15-22 m
Land-use	About 30% Agriculture Land
Source of Water	Sea (3.5 kms)

4.1 Physical processes

The various physical processes that play a major role in the effluent release and its dilution and removal from the area of release are tide, currents and circulation. The coastal environment off Bhadreswar forms an integral part of Gulf. Hence, the knowledge of the general ecology of the Gulf is necessary to understand the site- specific environmental conditions with that of the parent body.

The gulf which occupies an area of 7300 Km^2, has maximum depth that varies from 20 m at the head (Kandla – Navalakhi) to 60 m in the central regions. The actual fairway however is obstructed due to the presence of several shoals, needing periodic dredging in some areas, to facilitate navigation to Kandla port. The tidal scour which follows the axis of the Gulf has steep slopes and rugged surfaces. A number of scraps with relative elevation of 6 to 32 m occur on the sediment-free bed on the central Gulf.

All along the coast, very few rivers drain into the Gulf and they carry only a small quantity of freshwater, except during brief monsoon. They are broad-valleyed and the river beds are mostly composed of coarse sand and gravel. The Gulf is characterised by numerous hydrographic irregularities like pinnacles, as much as 10 m high. The southern shore has numerous islands and inlets covered with mangroves and surrounded by coral reefs. The northern shore is predominantly sandy or muddy confronted by numerous shoals.

The coastal configuration is very irregular with numerous islands, creeks and bays. Besides, there are a number of eroded shallow banks like Pirotan, Dide, Dhani, Paga, Adatra reefs along the southern shore, many of which harbour living corals. The intertidal region is sandy, muddy or rocky.

Tides in the Gulf are of mixed, predominantly semidiurnal type with a large diurnal inequality. The tidal front enters the gulf from the west and due to shallow inner regions and narrowing cross-sections, the tidal amplitude increases considerably, upstream of Sikka. Due to this high tidal ranges in the inner regions, the vast mudflats and coastal low lands which get submerged during the high tide are fully exposed during low tide.

The circulation in the Gulf is mainily controlled by the tidal flows and bathymetry through wind effect also prevails some extent. The maximum surface currents are moderate (0.7-1.2 m/s) but increases considerably (2.0-2.5m/s) in the central portion of the Gulf. The spring currents are 60 to 65% stronger than the neep currents. The bottom currents are also periodic with a velocity normally 70% of the surface currents.

With high tidal range, negligible land run-off and irregularities topography, the waters are vertically homogeneous in terms of salinity and temperature.

Central portion of the gulf extending from the mouth to upstream of Sikka is rocky with sediment confined only to the margins. The near shore sediment, which consists of light gray silt and clay and fine sand with patches of coarse sand in between, are poorly sorted with highly variable skewness. The major source of this sediment is considered to be the shore material and the load transported by the Indus river.

Rainfall and Temperature

The Kachchh is a semi-arid region with weak and erratic rainfall confined largely to June-October period. With a few rainfall days, the climate is hot and humid from April till October and pleasant during brief winter from December to February. Although the monthly mean maximum temperature recorded during 2005 is 37^{o}C, it occasionally exceeds 40^{o}C. Rainfall alone forms the ultimate source of freshwater resource to the region. The average rainfall at Mundra is about 400 mm/year and the precipitation in 2005 was close to this value.

Cyclones

Cyclonic disturbances strike North-Gujarat, particularly the Kachh and Saurashtra regions, periodically. These disturbances generally originate over the Arabian Sea and sometimes the Bay of Bengal. Generally during June, the storms are confined to the area north of 15^{o}N and east of 65^{o}E. In August, in the initial stages, they move along the northwest course and show a large latitudinal scatter. West of 80^{o}E, the tracks tend to curve towards north. During October the direction of movement of a storm is to the west in the Arabian Sea. However, east of 70E some of the storms move north-northwest and later recurve northeast to strike Gujarat-north Mekran coast.

Wind

There are strong winds at times at Mundra Port. The wind directions are shown in **Figure** below. In the period lasting over months March to May the wind direction is generally SWW (225˚ - 250˚) and velocity varies from 20 to 25 Knots. June through August the wind direction is predominantly SW and velocity varies from 25 to 30 Knots with short gusts going up to 35 to 40 Knots. Towards end of September and through October wind direction changes to NE with velocities ranging from 7 to 10 Knots. Direction remaining same the velocity varies 10 knots to 25 Knots in the period November to Jnauary. February is the calm period when wind direction is southerly with velocity in the range of 7 Knots. Stormy weather may generate winds having velocity up to 100 Knots which should be taken as the worst case scenario for design of tall structures and heavy duty cranes.

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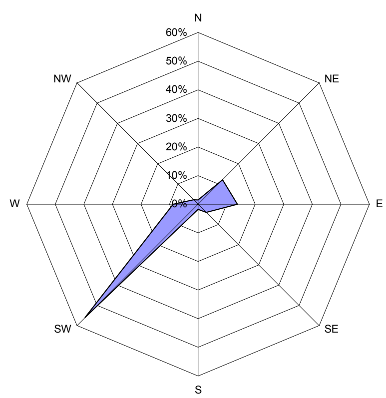
Generalized Wind Rose Diagram



Tides

The tidal planes were assessed in 1998 as shown in **Table**

The highest astronomical tide (HAT) is estimated to be about +6.4 m above chart datum (CD), and the lowest astronomical tide (LAT) to be at 0.0 m CD.

Table

Tide	Height (m) above CD
Mean High Water Springs	5.8
Mean High Water Neaps	4.6
Mean Low Water Neaps	2.1
Mean Low Water Springs	1.0

Currents

Currents at the proposed site of the Berths are almost aligned to the sea bed contours and are of the order of 2.5 to 3 Knots.

Humidity

Minimum is a little less than 65% highest being 85%.

Visibility

Visibility in this area is good except for short periods in early mornings for a few days in the month of January.

Soil Characteristics

At the time of writing this Report Geotechnical Data for the Berth location is not available but some Bore Holes have been run in the foreshore area. The available data gives strong indication that the soil characteristics at Wandh location are going to be slightly better if not identical to Mundra. From general soil profile section in North South direction it is inferred that there is strong possibility of reducing the length of the Piles in this area as compared to Mundra. Soil investigation work for the Terminal location is in progress and actual data shall be used for detailed design of the structures.

Seismic Conditions

The area falls in most active seismic zone as per IS 1893 (Zone V). This will be borne in mind and duly considered at the time of detailed design.

Waves

In past HR Wallingford (HRW) has studied the wave climate considering wave energy from locally generated waves and swell propagating in to the Gulf of Kachh from the Arabian Sea. The results of the study carried out by HRW are presented in the Table below:

Sediment Quality

Many pollutants when released in an aquatic environment are adsorbed onto particulate matter and/or precipitated in the changed matrix. Hence, subsequent settling of the particulate matter and precipitates on surfacial and intertidal bed sediment results in progressive enrichments of sediment by contaminants. Evidently, sediments act as an ultimate sink for several pollutants.

5 Hydrodynamic Model Studies

5.1 Hydrodynamic model

5.1.1 Basic governing equations

The basic governing equations of flow are solved numerically in simulation of tides and currents in the coastal environments. These equations are formulated based on incompressible flow and vertically integrated hydrostatic distribution since the vertical acceleration of the flow is much smaller than the pressure gradient. After applying these assumptions, the basic governing equations of flow momentum can be written in the conservation form as follows:

5.1.2 Continuity equation

$$\frac{\partial \eta}{\partial t} + \frac{\partial uH}{\partial x} + \frac{\partial vH}{\partial y} = 0$$

5.1.3 Momentum equations

The two depth-averaged momentum equations can be written as

$$\frac{\partial uH}{\partial t} + \frac{\partial u^2 H}{\partial x} + \frac{\partial uvH}{\partial y} = fvH - gH\frac{\partial \eta}{\partial x} + H\frac{\partial}{\partial x}\left(K_x \frac{\partial u}{\partial x}\right) + H\frac{\partial}{\partial y}\left(K_y \frac{\partial u}{\partial y}\right) + \tau_{wx} - \tau_{bx}$$

$$\frac{\partial vH}{\partial t} + \frac{\partial vuH}{\partial x} + \frac{\partial v^2 H}{\partial y} = -fuH - gH\frac{\partial \eta}{\partial y} + H\frac{\partial}{\partial x}\left(K_x \frac{\partial v}{\partial x}\right) + H\frac{\partial}{\partial y}\left(K_y \frac{\partial v}{\partial y}\right) + \tau_{wy} - \tau_{by}$$

where, t = time; x, y are Cartesian co-ordinates; u and v are depth averaged velocity components in the x and y directions, respectively; f = Coriolis parameter; g = acceleration due to gravity; Kx, Ky diffusion coefficients in the x and y directions, respectively; η = water elevation with respect to mean sea level, H = total water depth at any instant.

5.1.4 Boundary Fitted Coordinate (BFC) system

In the Cartesian or rectilinear co-ordinate system, which is generally used in all global models, it is difficult to represent the complex coastline accurately, as grid size remains the same at any given location. To better resolve complex geometries

in the horizontal directions, the model makes the computations on the boundary-fitted Coordinate (BFC) or generalized curvilinear Coordinate system as shown in Fig.3. This necessitates the transformation of the governing equations into boundary-fitted coordinates (ς,σ). However, in the model the (x, y) coordinates are transformed in such a way that their components are perpendicular to the (ς,σ) coordinate lines. This is accomplished by employing the chain rule transformation.

The momentum equation in the x direction can be written in BFC system as

$$\frac{\partial(uH)}{\partial t}+\varsigma_x\frac{\partial(u^2H)}{\partial\varsigma}+\sigma_x\frac{\partial(u^2H)}{\partial\sigma}+\varsigma_y\frac{\partial(uvH)}{\partial\varsigma}+\sigma_y\frac{\partial(uvH)}{\partial\sigma}-fvH+$$
$$gH\left(\varsigma_x\frac{\partial\eta}{\partial\varsigma}+\sigma_x\frac{\partial\eta}{\partial\sigma}\right)-HK_x\left(\varsigma_{xx}\frac{\partial u}{\partial\varsigma}+\sigma_{xx}\frac{\partial u}{\partial\sigma}+(\varsigma_x)^2\frac{\partial^2u}{\partial\varsigma}+(\sigma_x)^2\frac{\partial^2u}{\partial\sigma}+2\varsigma_x\sigma_x\frac{\partial^2u}{\partial\varsigma\partial\sigma}\right)-$$
$$HK_y\left(\varsigma_{yy}\frac{\partial u}{\partial\varsigma}+\sigma_{yy}\frac{\partial u}{\partial\sigma}+(\varsigma_y)^2\frac{\partial^2u}{\partial\varsigma}+(\sigma_y)^2\frac{\partial^2u}{\partial\sigma}+2\varsigma_y\sigma_y\frac{\partial^2u}{\partial\varsigma\partial\sigma}\right)-\tau_{wx}+\tau_{bx}=0$$

Where, $\varsigma_x,\varsigma_y,\sigma_x,\sigma_y,\varsigma_{xx},\varsigma_{yy},\sigma_{xx},\sigma_{yy}$ grid transformation parameters

K_x, K_y = diffusion coefficients in x, y directions

H = total water depth at any time

h = water depth upto mean sea level

η = water elevation with respect to mean sea level

H = h+η

Similarly, the other momentum equation in the y direction and continuity equation can be written in the BFC coordinate system as described above. More details about transformation of basic governing equation of flow can be found in Reddy (1994).

5.1.5 Diffusion coefficients

The horizontal diffusion coefficients K_x and K_y are calculated as follows:

$$K_x = \alpha_x g\left(\sqrt{u^2 + v^2}\right) / C^2$$

$$K_y = \alpha_y g\left(\sqrt{u^2 + v^2}\right) / C^2$$

where α_x and α_y are the diffusion factors in x and y directions and C is the Chezy's coefficient.

5.1.6 Numerical solution algorithm

The transformed governing equations of flow have been discretized on a staggered grid and solved using Leapfrog trapezoidal scheme through a predictor and corrector step method. The scheme is fully centered in space and time and can obtain 2nd order accuracy. The scheme consists of two level computations (predictor and corrector steps) within the time step Δt.

$$F(K^n)=(K^* - K^{n-1})/(2\Delta t)$$

$$F(K^n)+F(K^*)=2(K^{n+1} - K^n)/(\Delta t)$$

Where, K* = predicted variable level. The grid transformation derivatives $(\sigma_x, \varsigma_x, \sigma_y, \varsigma_y)$ can be specified at the cell centers and cell mid-faces.

Since the range of the co-ordinates in the computational plane is completely arbitrary, the mesh increments are specified as unity for convenience. Consequently, the geometric variables are defined on a finite difference mesh with cell increments of 0.5. The computations have been carried out for the next time step through predictor and corrector schemes using the above finite difference quotients.

5.2 Model description

Dedicated softwares Hydrodyn-FLOSOFT, Hydrodyn-POLSOFT and Hydrodyn-SEDSOFT for prediction of tides and currents, dilution & dispersion and sedimentation processes in the seas and estuaries developed at Environ Software (P) Ltd, Bangalore, based on solving the hydrodynamic equations numerically through coupled way using the present state-of-art of technology are utilized for the studies.

5.3 Model setup and calibration

5.3.1 Boundary conditions

The region of study, in the Bhadreshwar region is shown in Fig. 1. The computational domain of the model is selected between the longitude 69°50' 52.8"E and 70° 07' 15.6" E and the latitudes of 21°41' 20"N and 22°58' 57''N is selected for carrying out sensitivity analysis and extended for predicting the flow regime due to proposed marine facilities at Bhadreshwar. The model domain is divided into various computational blocks and generated the grids in x and y directions respectively. Fig. 3 shows the computational grid for the Bhadreshwar region.

The bathymetry is selected from the measured hydrographic chart data. The interpolated bathymetric depth contours are shown Fig. 4. From the figure It can observed that the maximum bathy depth is around 30m.

5.3.2 Bed roughness

The bottom roughness in the domain varies according to bed sediment grain sizes. The bed consists of various sizes of clay, sand and silt. Depending upon bed configuration and sediment sizes, the d_{50} size varies from 0.001m to 0.005m. In the present study constant Manning's roughness coefficient is selected based on the validation and the same is used for carrying out various computational runs for the prediction of hydrodynamic parameters in the Bhadreshwar flow filed system. The software has been run for various sets of Manning roughness coefficient (0.03 to 0.056) till the discrepancy is minimum in the prediction of tides and currents. From the series of computational runs, the Manning coefficient 0.056 is found to be best for model calibration. The bed roughness contours (Chezy's bed roughness coefficient) has been calculated based on Manning roughness and water depth and shown in Fig. 5. From the Fig.5, it can be observed that the roughness coefficient varies from 0 to 24. The model has been run for various inputs using the same roughness coefficient in the prediction of tide and currents in the Bhadreshwar region.

5.3.3 Initial and boundary conditions

The initial conditions for the model are selected based on still water conditions. The vertical density gradients due to salinity variation have been neglected since the water column is well mixed. The BFC technique has been adopted to take care of shoreline shape and make fine mesh near the coastline. The grid is non-uniform both in x and y directions and it is a fine mesh.

The open boundary conditions identified southern open boundary, and north boundary are closed. The boundary conditions selected are as follows. (i) 2009 tide at Bhadreshwar (Fig.2) (ii) no flow boundary conditions at northern and (iii) no flow across the coastal boundary. In this model, diffusion coefficients for horizontal exchange of momentum varies with the space.

5.3.4 Model calibration

The interpolated Chezy's coefficients calculated based on Manning's roughness and water depth is shown in Fig. 5. The sensitivity analysis has been carried out with various sets of variable bed roughness coefficients, which are the combined effect of d_{50} sediment size and bed configuration in order to calibrate the model with respect to the tide data of May tide data at Bhadreshwar. The computational runs were continued with various sets of bed roughness values to calibrate the model. Fig. 5 show the variation of Chezy's coefficient in the Bhadreshwar due to variable bed roughness adopted for the model calibration. The input tide (at Bhadreshwar) used for the modeling as open boundary condition.

A comparison has been made between the observed and computed tides at Bhadreshwar is shown in Fig. 6. From the figure it can be said that discrepancy is within the acceptable limits (<1%) for water levels computed.

The model runs have been made for a period of 15 days covering spring and neap tide conditions to obtain an insight into the basic hydrodynamic behaviour of the Bhadreshwar

5.4 Modelling for tides and currents

The model clearly reproduces the tidal variation at various locations in the Bhadreshwar. The typical tidal velocities for Low Water(LW), High Water (HW), Peak Flood and Peak Ebb are discussed in the following sections.

5.4.1 Tidal currents during Low Water (LW) condition

Fig.7and Fig.11 show the spatial variation of velocities during low water tide condition of neap and spring tides. From the figure it can be seen that the flow direction changes from east to west.

The flow velocity is around 0.052 m/sec- 0.27 m/sec at the central. From the figure, it can be observed that the intertidal areas in northern coast and are exposed during the low water condition.

5.4.2 Tidal currents during Peak Flood

The spatial variation of velocities at different locations in the Bhadreshwar during peak flood of spring and neap condition are shown in Fig. 8 & Fig. 12 From the figure, it can be seen that the flow direction is from east to west. The maximum current speed is 0.45 m/sec at around intake. During this period the currents are stronger than EBB, LW and HW tide condition.

5.4.3 Tidal currents during Highest High Water(HHW)

Fig.9 and Fig.13 show the spatial variation of velocities during High water tide condition of neap and spring tides. From the figure it can be seen that the flow direction changes flood to ebb. The flow velocity is around 0.04 m/sec- 0.09 m/sec. From the figure, it can be observed that the intertidal areas in northern coast and are covered during this HW condition.

5.4.4 Tidal currents during Peak Ebb

The spatial variation of velocities at different locations in the Bhadreshwar during peak ebb condition of neap & spring tides condition are is shown in Fig. 10 & Fig.14. From the figure, it can be seen that the flow direction is from east to west. The maximum current speed is about 0.45 m/sec.

6. Thermal dispersion studies

The power plant will return the intake water to the Gulf through discharge channel and outfall structure with chemical composition unchanged, with a temperature increase of 4.5 ^{0}C. The effluent parameter considered for the present study is temperature at the disposal is shown in Fig. 15.

6.1 Modeling of temperature for GPPC outfall discharge

The computational runs in order to obtain better accuracy in the prediction of variation water quality parameters, a finer mesh is adopted to represent the study area for modeling purpose. The study domain is between Latitude 21°41' 20'N and 22°58' 57''N and Longitude 69°50'52.8"E and 70° 07' 15.6" E shown in Fig 23 and Fig. 61 along with terrain features including intake and outfall locations. The domain is divided into 100 x 50 grids in "x" and "y" directions respectively, shown in Fig. 3.

The computation runs have been made for the proposed intake and outfall to predict the changes in the water qualities and temperature considering ambient sea water temperature of 28^{0} C for a period of 15 days. The runs considering peak flood, peak ebb, lowest low water and highest high water level have been made for spring and neap tide condition and results are presented graphically and discussed in the following sections.

6.1.1 Neap tide condition

The results pertaining to variation of temperature at various locations for neap tide condition are shown graphically and discussed below.

Fig. 16 show the variation of temperature for LW tide condition of 0.5 m during neap tide of outfall. from the figures that temperature spread is around the source, and in both seasons are similar. It can be observed from the figures that within 60 m, the temperature has come down to 0.4 deg C above ambient and dispersed & convected away from the outfall location towards westward from the outfall location.

(a) . Fig.17 shows the variation of temperature for peak flood tide condition during neap tide for outfall location. From the above figures it can be observed that the convection and dispersion of temperature is more due to increase in the resultant velocity of flow. However, the trend in both cases are similar and can be observed from the figures that within 100 m the temperature has around 0.4 Deg C above ambient and dispersed and convicted eastwards towards mouth of intake channel, but there is no increase of temperature at intake observed.

(b) Fig.18 show the variation of temperature for HW tide condition during neap tide of outfall option respectively It can be observed from the figures that the temperature is dispersed at and around the source and not dispersing towards intake channel. The temperature has about 0.4 deg C above the ambient with in 100 m from the outfall location and dispersed around the outfall location.

(c) Fig.19 show the variation of temperature for peak ebb tide condition during spring and neap tide of outfall. It can be observed from the figure that within 100 m the temperature has about 0.35 Deg C above ambient and convected towards eastern outfall location. It also can be observed from the figures that the temperature is convected and dispersed more in this period.. However, during this period the temperature is convected and dispersed in western direction of outfall location.

The variation of temperature during neap tide conditions at different locations are shown in Fig. 33 & Fig. 34 From the figures it can be seen that the temperature during neap and spring tide are well within the acceptable limit at the mouth of intake channel,. Hence, from the figures it can be concluded that there will not be any thermal recirculation and impact on water qualities due the proposed outfall discharge

6.1.2 Spring tide condition

The results pertaining to variation of temperature at various locations for spring tide condition are shown graphically and discussed below.

(a) Fig. 20 show the variation of temperature for LW tide condition of 0.5 m during neap tide of outfall. It can be seen from the figures that temperature spread is around the source and in both seasons are similar. It can be observed from the figures that within 60 m the temperature has about 0.4 deg C above ambient and dispersed & convected away from the outfall location towards westward from the outfall location.

(d) Fig. 21 shows the variation of temperature for peak flood tide outfall location. it can be observed that the convection and dispersion of temperature is more due to increase in the resultant velocity of flow. However, the trend in both cases are similar and can be observed from the figures that within 100 m the temperature has come down to around 0.4 Deg C above ambient and dispersed and convicted eastwards towards mouth of intake channel, but the no increase in temperature is observed at the intake point.

(e) Fig. 22 show the variation of temperature for HW tide condition during spring and neap tide It can be observed from the figures that the temperature is dispersed at and around the source and not dispersing towards intake channel. The temperature has increase to 0.4 Deg C above the ambient with in 100 m from the outfall location and dispersed around the outfall location.

(f) Fig. 23 show the variation of temperature for peak ebb tide condition outfall option respectively. I It can be observed from the figure that within 100 m the temperature increased to 0.35 Deg C above ambient and convected towards eastern outfall location. It also can be observed from the figures that the temperature is convected and dispersed more during this period.. However, during this period the temperature is convected and dispersed in western direction of outfall location.

The variation of temperature during neap tide conditions at different locations for outfall shown in Fig. 33 & Fig. 34. From the figures it can be seen that the temperature during neap and spring tide condition are well within the acceptable limit at the mouth of intake channel. Hence, from the figures it can be concluded that there will not be any thermal recirculation and impact on water qualities due the proposed outfall discharge.

Summary of results of thermal recirculation

Fig. 33 & Fig. 34 show the variation of temperature and tide at various locations during neap and spring tide condition outfall locations From the Figures it can be concluded that the excess temperature rise for intake does not effected. Hence, the proposed outfall and intake locations are suitable for all hydrological, oceanographic and meteorological conditions of Bhadreshwar region.

7. Salinity dispersion Studies

The power plant and RO plant will return the intake water to the open waters at Bhadreswar through discharge channel with chemical composition unchanged, with a salinity increase of 4 ppt. The effluent parameter considered for the present study is salinity at the disposal locationis shown in Fig. 23

7.1 Modeling of salinity for KPGL outfall discharge

In order to obtain better accuracy in the prediction of variation water quality parameters a finer mesh is adopted in the computational runs to represent the study area for modeling purpose. The study domain is between Latitude 21°41' 20'N and 22°58' 57''N and Longitude 69°50'52.8"E and 70° 07' 15.6"E shown in Fig 15 along with terrain features including intake and outfall locations. The domain is divided into 100 x 50 grids in "x" and "y" directions respectively, shown in Fig. 3.

The computation runs have been made for the proposed intake and outfall to predict the changes in the flow regime and salinity considering ambient sea water salinity of 36 ppt for a period of 25 days. The runs considering peak flood, peak ebb, lowest low water and highest high water level have been made for spring and neap tide condition and results are presented graphically and discussed in the following sections.

7.1.1 Neap tide condition

The results pertaining to variation of salinity at various locations for neap tide condition are shown graphically and discussed below.

(a) Fig. 24 show the variation of salinity for LW tide condition of 0.5 m during neap tide of outfall. It can be seen from the figures that salinity spread is around the source and in both seasons are almost similar. It can be observed from the figures that within 60 m the salinity has observed to be 1 ppt above ambient and dispersed & advected away from the outfall location towards westward from the outfall location.

(b) Fig.25 shows the variation of salinity for peak flood tide condition during neap tide outfall location. From the above figures it can be observed that the convection and dispersion of salinity is more due to increase in the resultant velocity of flow. However, the trend in both cases are similar and can be observed from the figures that within 100 m the salinity has around 1 ppt above ambient and dispersed and advected eastwards to the mouth of intake channel, but the no increase in salinity at intake is observed.

(c) Fig.26 show the variation of salinity for HW tide condition during neap tide outfall option .Fig. It can be observed from the figures that the salinity is dispersed at and around the source.. The salinity has increased to 0.4 Deg C above the ambient within 100 m from the outfall location and dispersed around the outfall location.

(d) Fig.27 show the variation of salinity for peak ebb tide condition during neap tide outfall option It can be observed from the figure that within 100 m the salinity has around 1 ppt above ambient and convected towards eastern outfall location. It also can be observed from the figures that the salinity is advected and dispersed more during this period.. However, during this period the salinity is advected and dispersed in western direction of outfall location.

The variation of salinity during neap tide conditions at different locations for are shown in Fig. 35 & Fig. 36 From the figures it can be seen that the salinity during neap and spring tide condition of are well within the acceptable limit at the mouth of intake channel,. Hence, from the figures it can be concluded that there will not be any thermo-saline recirculation and impact on water qualities due the proposed outfall discharge in case of both alternatives.

7.1.2 Spring tide condition

The results pertaining to variation of salinity at various locations for spring tide condition are shown graphically and discussed below.

Fig. 28 show the variation of salinity for LW tide condition of 0.5 m during neap tide of outfall. It can be seen from the figures that salinity spread is around the source and in both seasons are similar. It can be observed from the figures that within 60 m the salinity is about 1 ppt above ambient and dispersed and advected away from the outfall location towards westward from the outfall location.

(a) Fig. 29. shows the variation of salinity for peak flood tide condition during neap and spring tide outfall location From the above figures it can be observed that the convection and dispersion of salinity is more due to increase in the resultant velocity of flow. However, the trend in both cases are similar and can be observed from the figures that within 100 m the salinity is around 1 ppt above ambient, and dispersed and advected eastwards towards mouth of intake channel, but the no increase in salinity is observed at the intake.

(b) Fig. 30 show the variation of salinity for HW tide condition during spring and neap tide .It can be observed from the figures that the salinity is dispersed at and around the source and not dispersing towards intake channel. In alternative-2 option, it is dispersing towards the coast and can see the salinity is around 1 ppt. The salinity is around 1 ppt above the ambient with in 100 m from the outfall location and dispersed around the outfall location.

(c) Fig. 31 show the variation of salinity for peak ebb tide condition during spring and neap tide of outfall. It can be observed from the figure that within 100 m the salinity has come down to 1 ppt above ambient and convected towards eastern outfall location. It also can be observed from the figures that the salinity is convected and dispersed more during this period.. However, during this period the salinity is advected and dispersed in western direction of outfall location.

The variation of salinity during neap tide conditions at different locations for outfall alternative-1 and alternative-2 options are shown in Fig. 35 & Fig36 From the figures it can be seen that the salinity during neap and spring tide are well within the acceptable limit at the mouth of intake channel,. Hence, from the figures it can be concluded that there will not be any impact on water qualities due the proposed outfall discharge in case of both Alternatives.

7.2 Summary of results of salinity variations

Fig. 35 & Fig. 36 show the variation of salinity and tide at various locations during neap and spring tide outfall locations From the Figures it can be concluded that the excess salinity rise for intake does not affect the intake locations. Hence, the proposed outfall and intake locations are suitable for all hydrological, oceanographic and meteorological conditions of Bhadreshwar region.

8 Conclusions and Recommendations

Based on the modeling study carried out to evaluate the dispersion patterns of intake and outfall locations for the proposed thermal outfall discharge, sedimentation processes the following conclusions could be drawn.

- The model generated tides are comparable to actual observations at Bhadreswar.
- The model has been run for various tidal conditions to study the hydrodynamic behavior and flow regime in and around the proposed intake channel, outfall location, at Bhadreswar, Gulf of Kutch.
- The changes in the water qualities (Salinity &Temperature) over the ambient of waters do not seem to have significant changes due outfall discharges of thermal effluents to a quantity of 5,00,000 m3/hr with temperatures of 4.5°C and salinity of 4 ppt above ambient condition of water. It is evident that the there is no thermal recirculation and no impact on water qualities due to the proposed outfall discharges.
- The proposed intake and outfall location is suitable for all hydrological and meteorological conditions of Bhadreswar, However, as per the economical feasibility, alternative studies should be carried out for outfall.

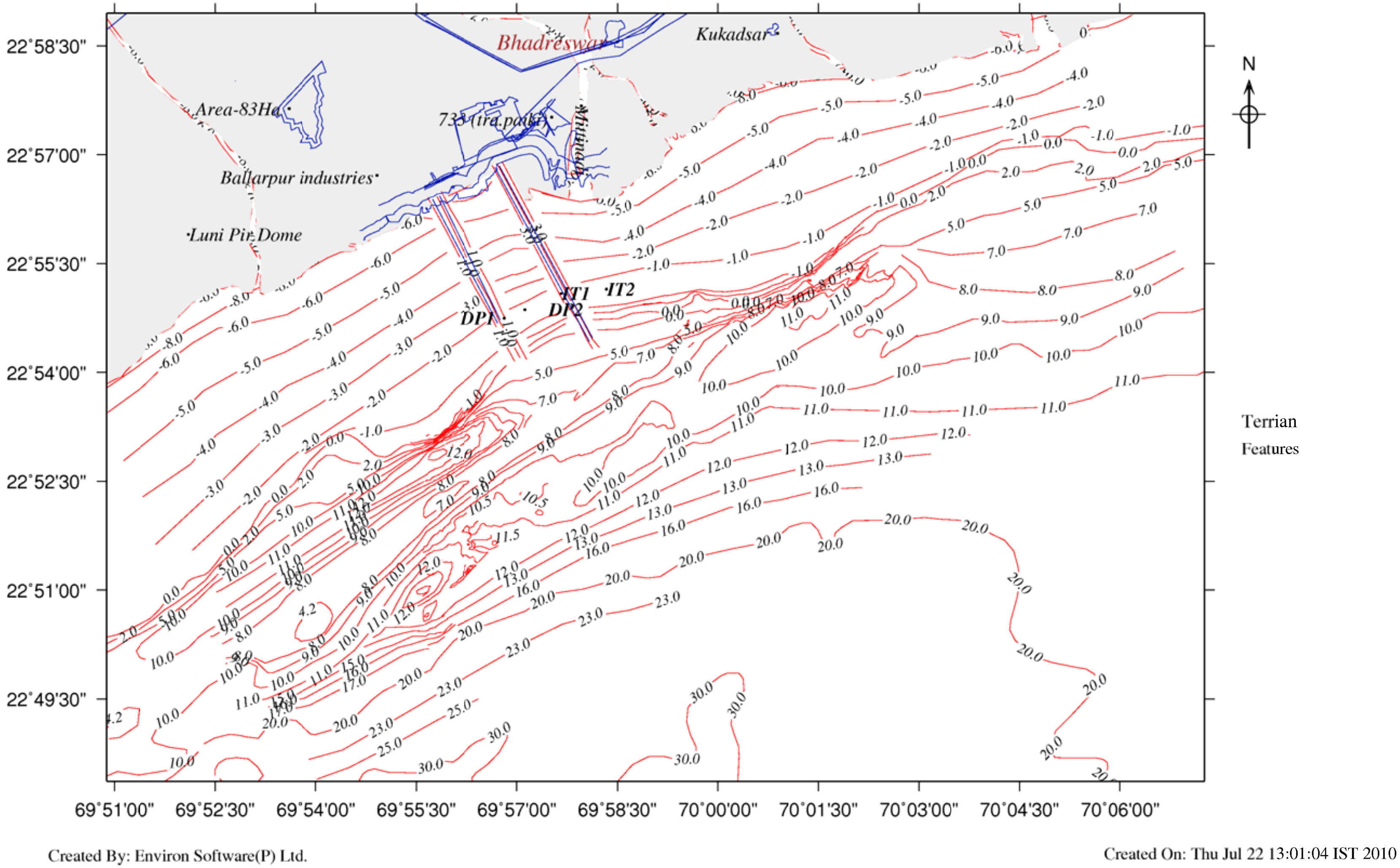


Fig.1 Terrain features of Kutch Power Generation Limited at Bhadreswar

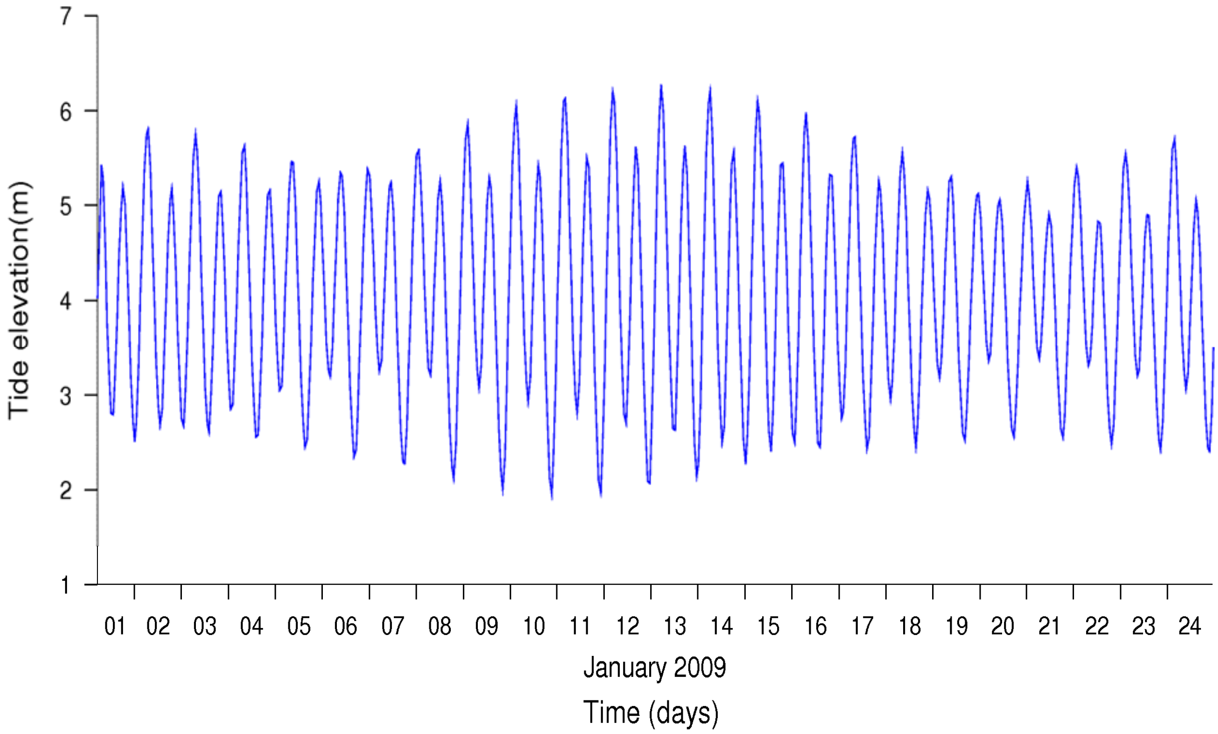


Fig. 2 Tides at computational boundary

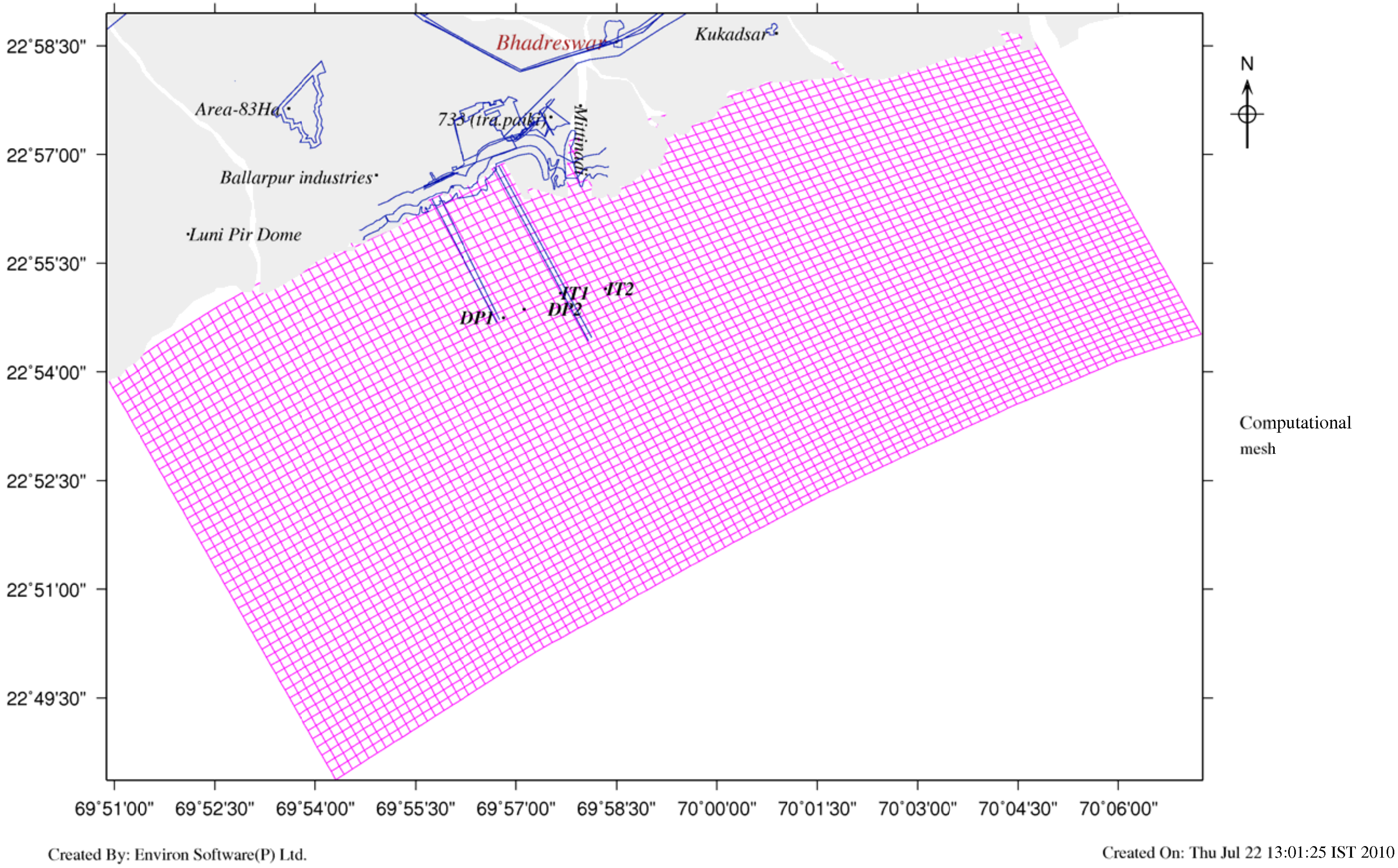


Fig.3 Computational BFC grid

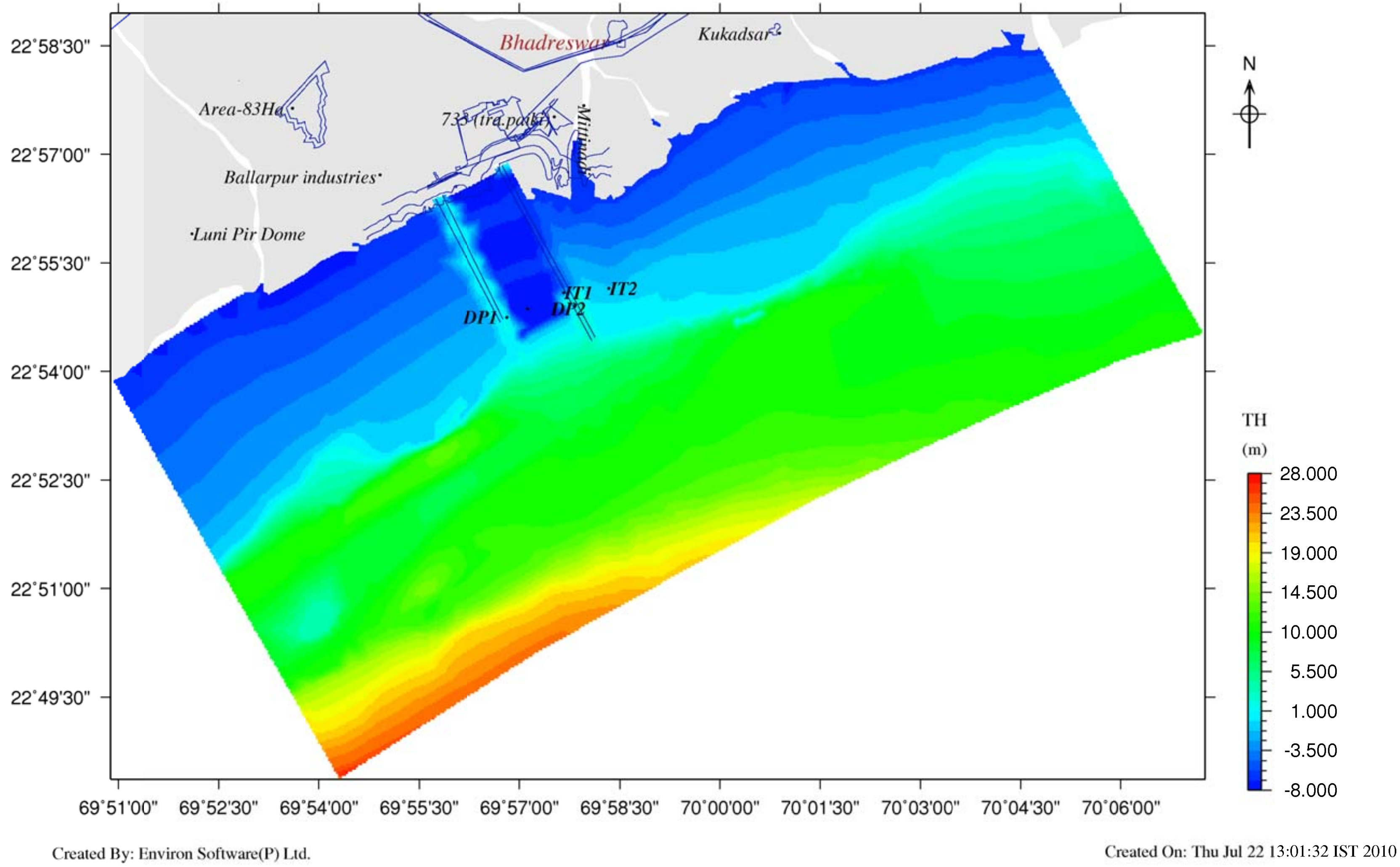


Fig.4 Contours of computed bathy depths (m)

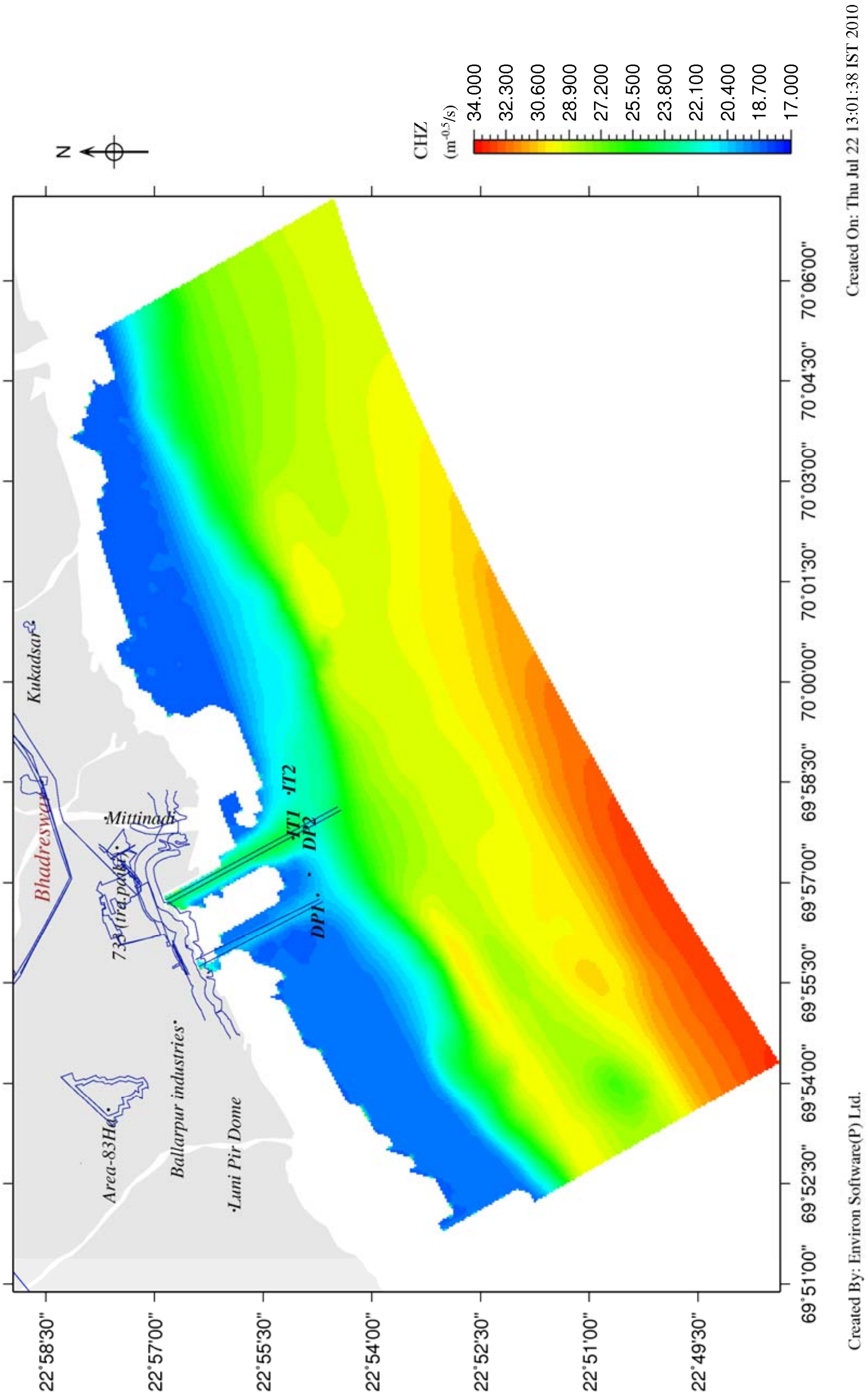


Fig.5 Interpolated Chezy's coefficients

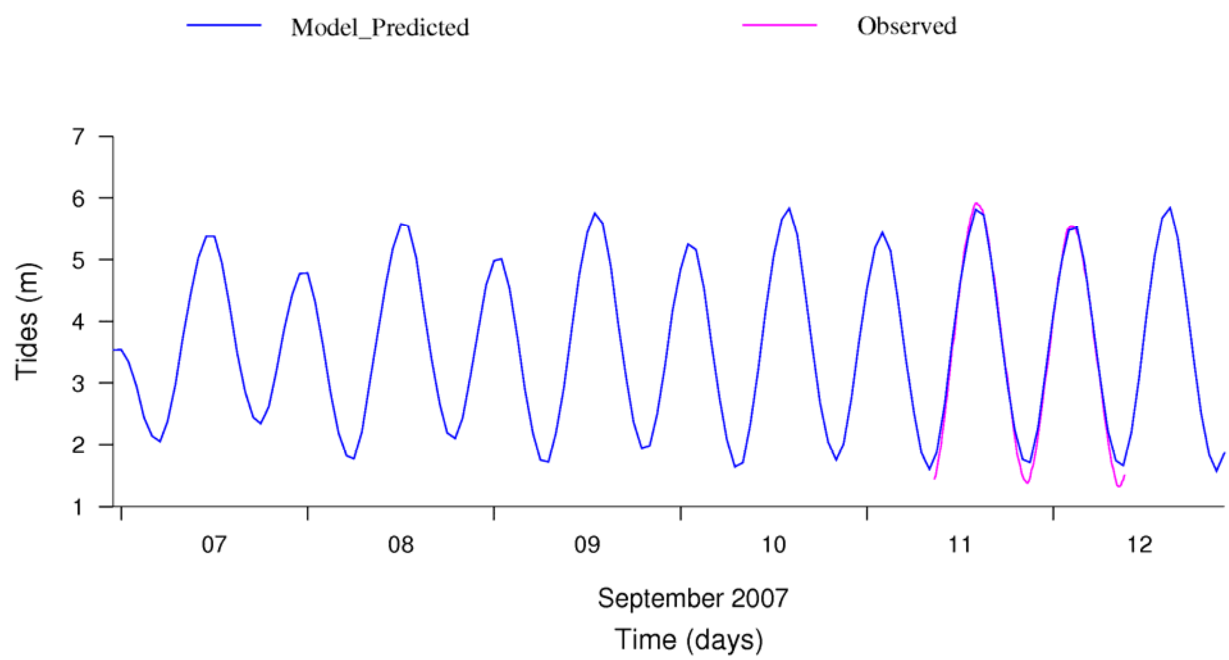


Fig.6 Comparison of computed and measured tides at Bhadreswar

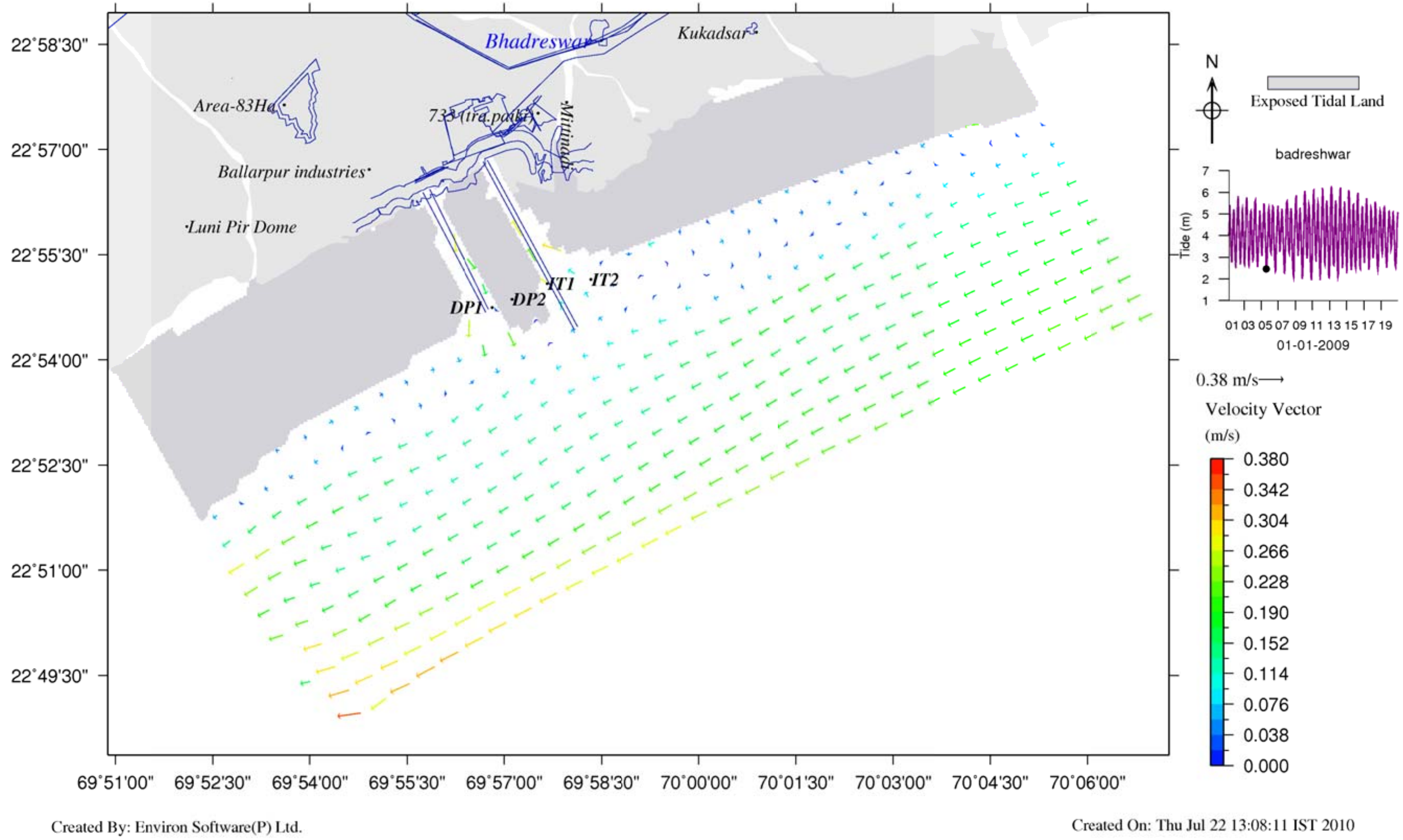


Fig.7 Simulated currents at 15hrs of 5th January 2009 during neap tide (LW)

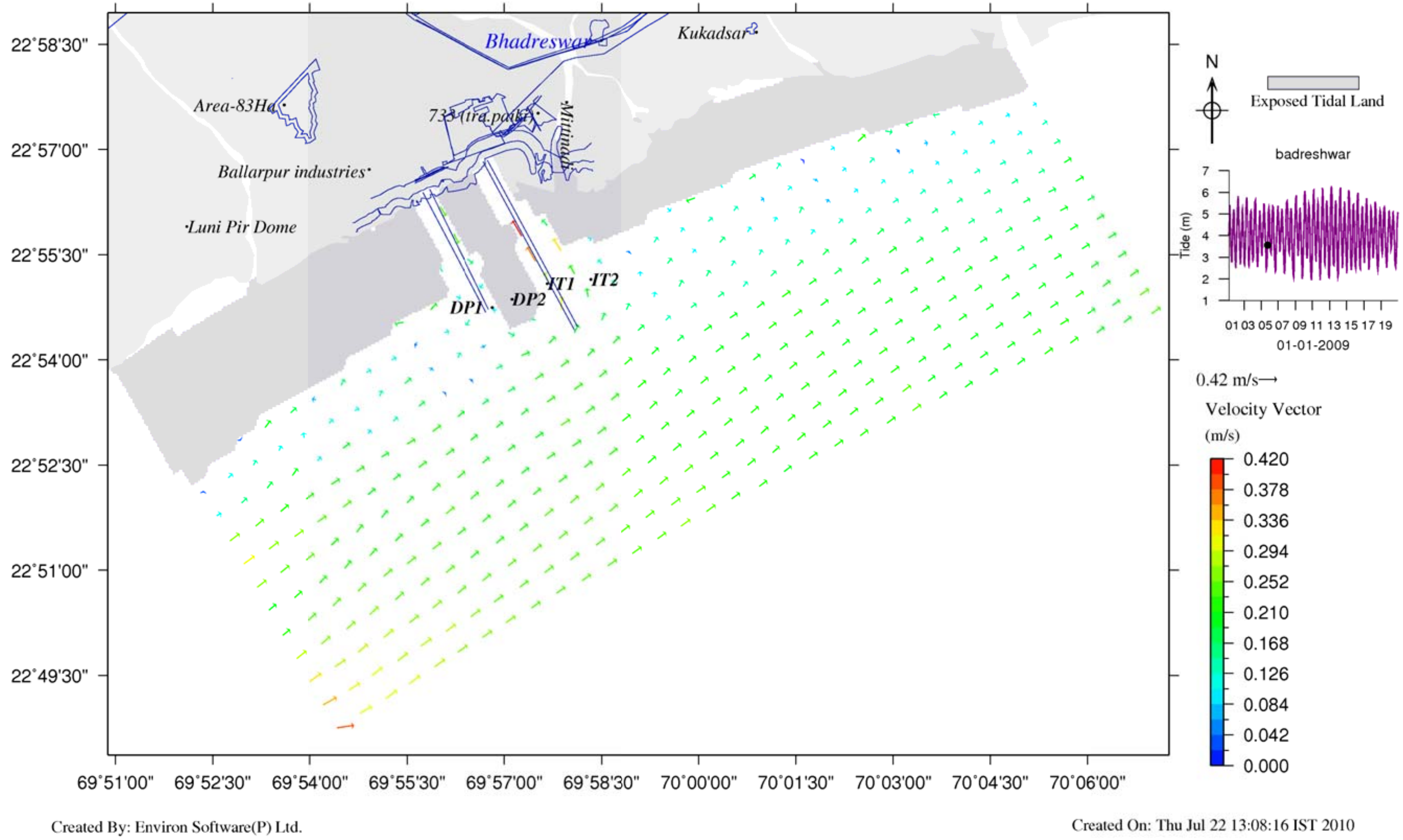


Fig.8 Simulated currents at 19hrs of 5th January 2009 during neap tide (Peak Flood)

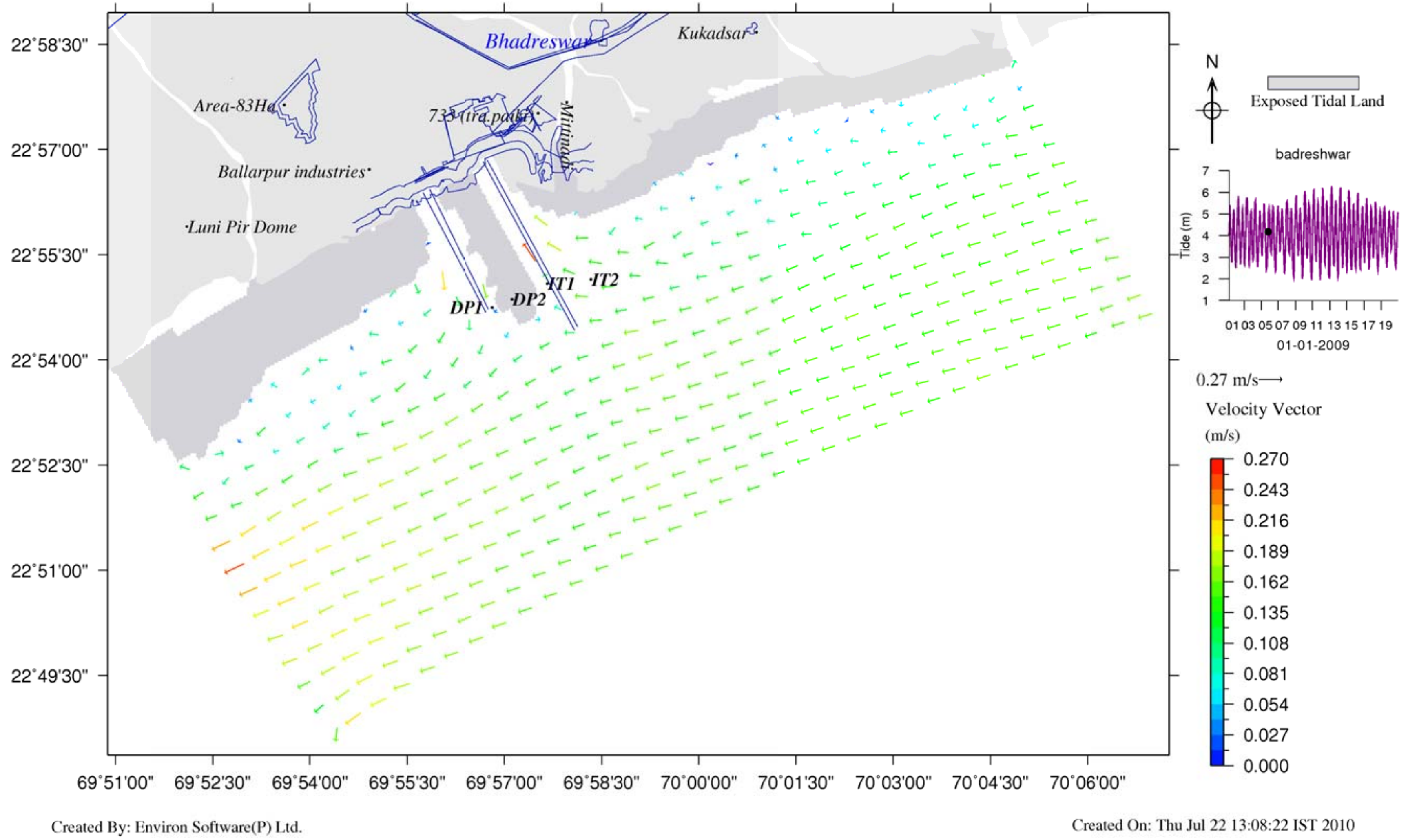


Fig.9 Simulated currents at 22hrs of 5th January 2009 during neap tide (HW)

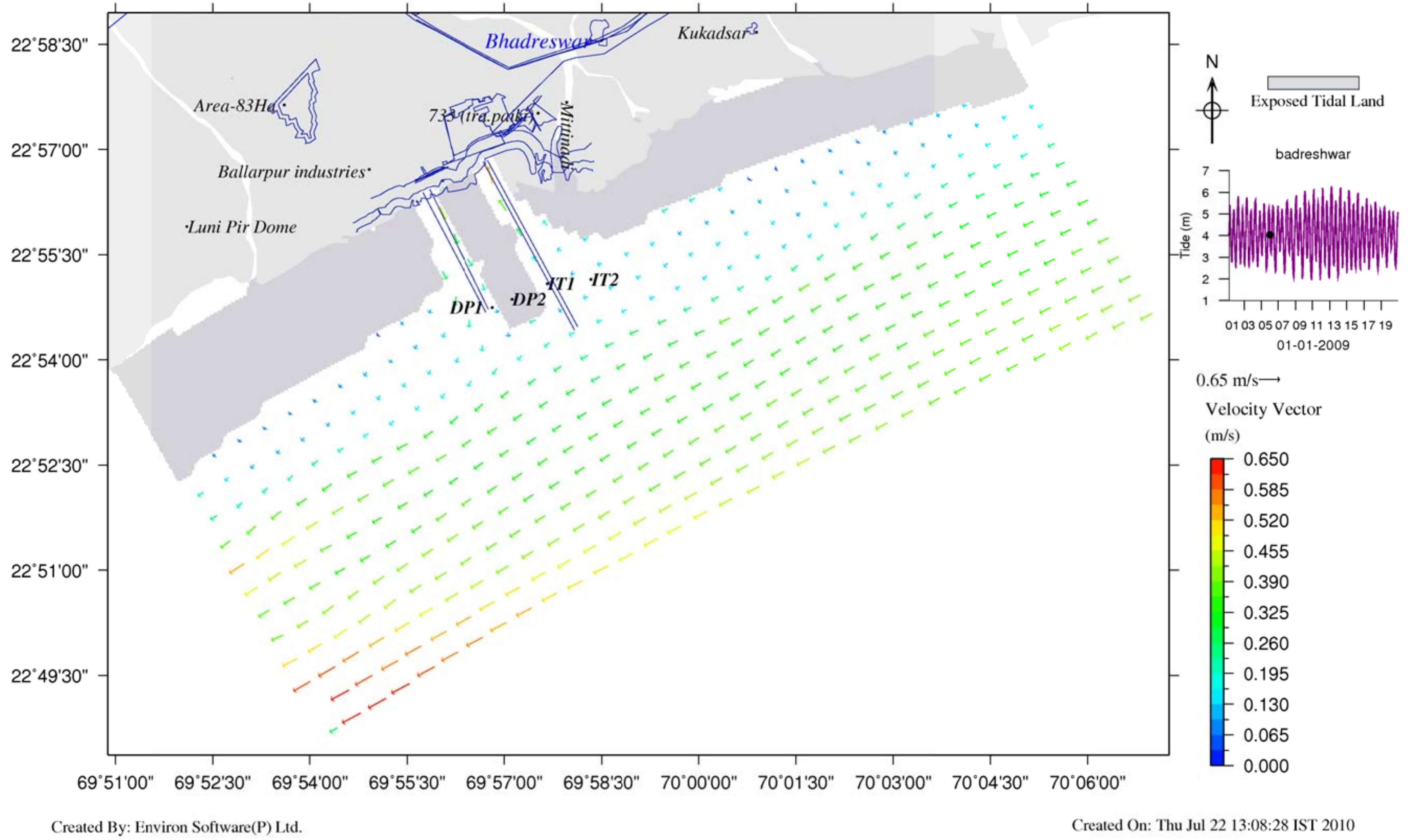


Fig.10 Simulated currents at 01hrs of 6th January 2009 during neap tide (Peak ebb)

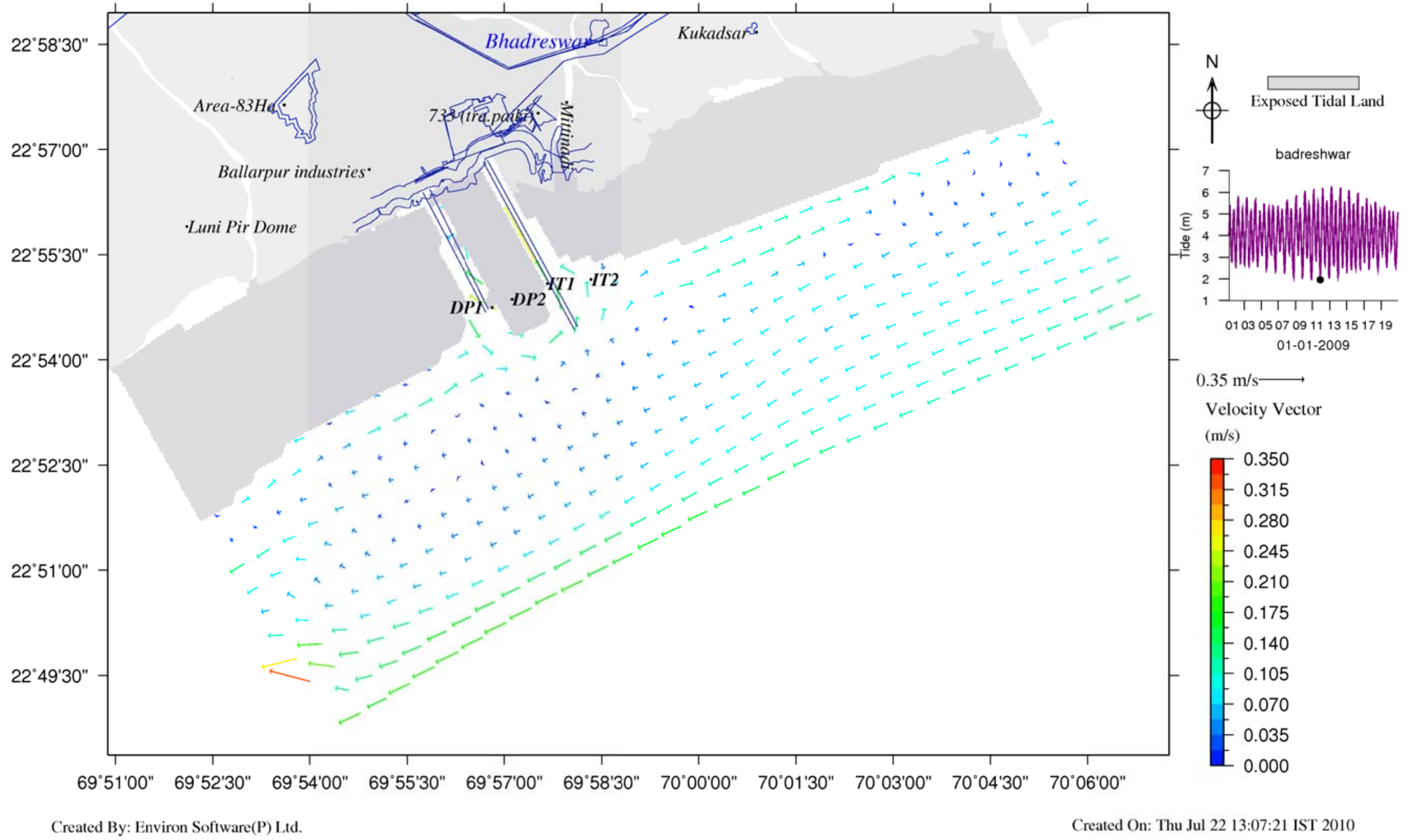


Fig.11 Simulated currents at 22hrs of 11th January 2009 during spring tide (LW)

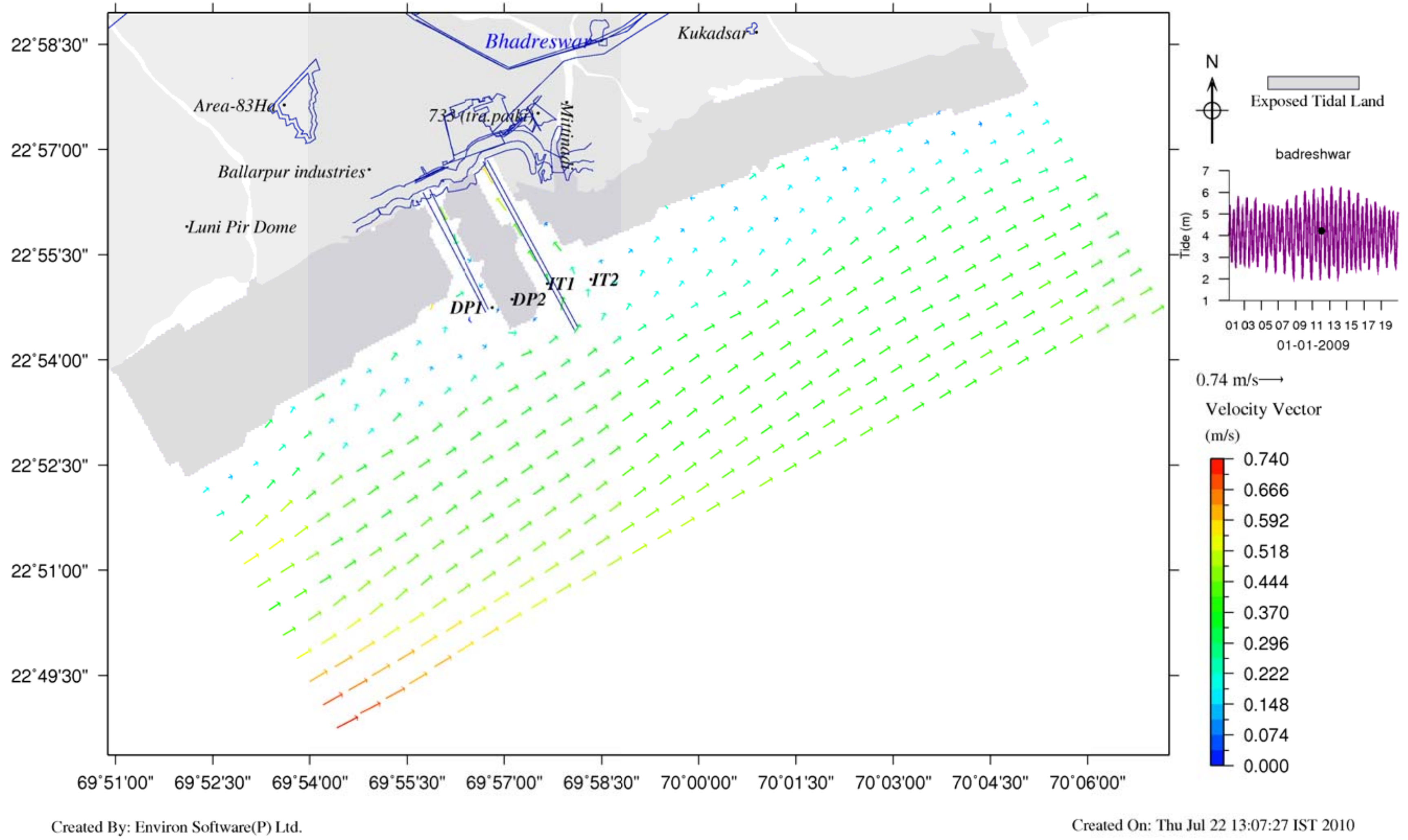


Fig.12 Simulated currents at 01hrs of 12th January 2009 during spring tide (Peak Flood)

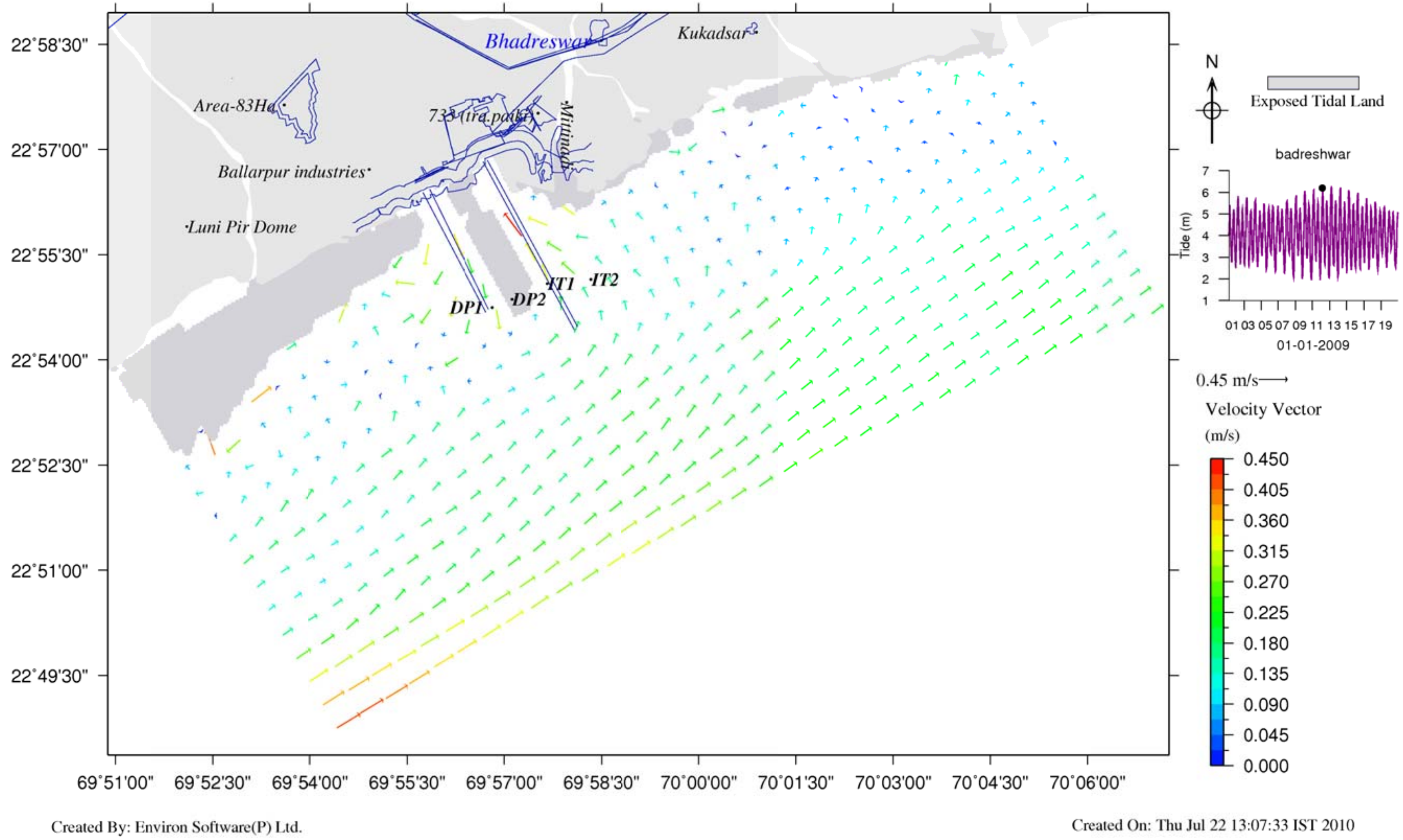


Fig.13 Simulated currents at 04hrs of 12th January 2009 during spring tide (HW)

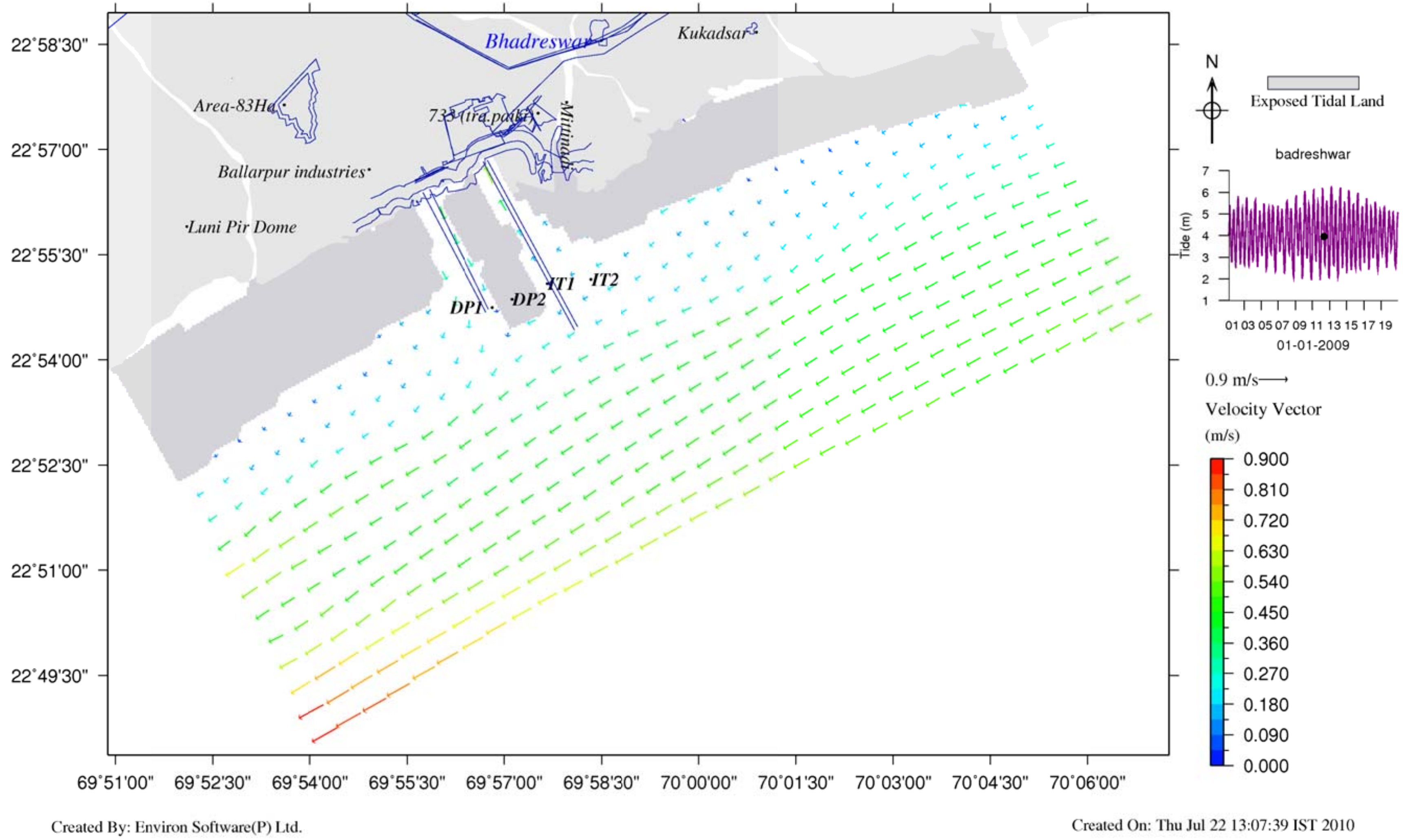


Fig.14 Simulated currents at 08hrs of 12th January 2009 during spring tide (Peak ebb)

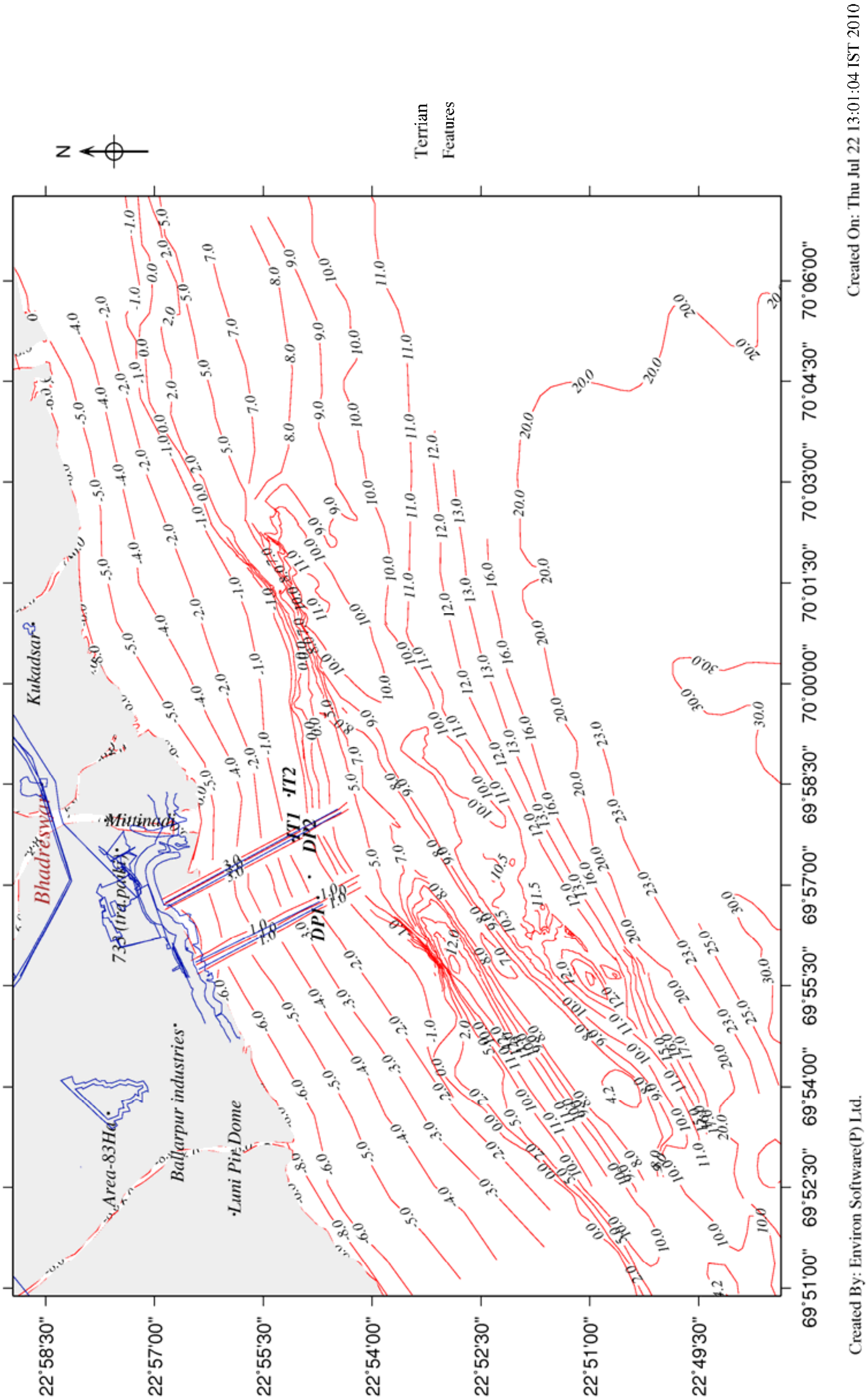


Fig. 15 Layout of Intake and outfall channels at Badreshwar

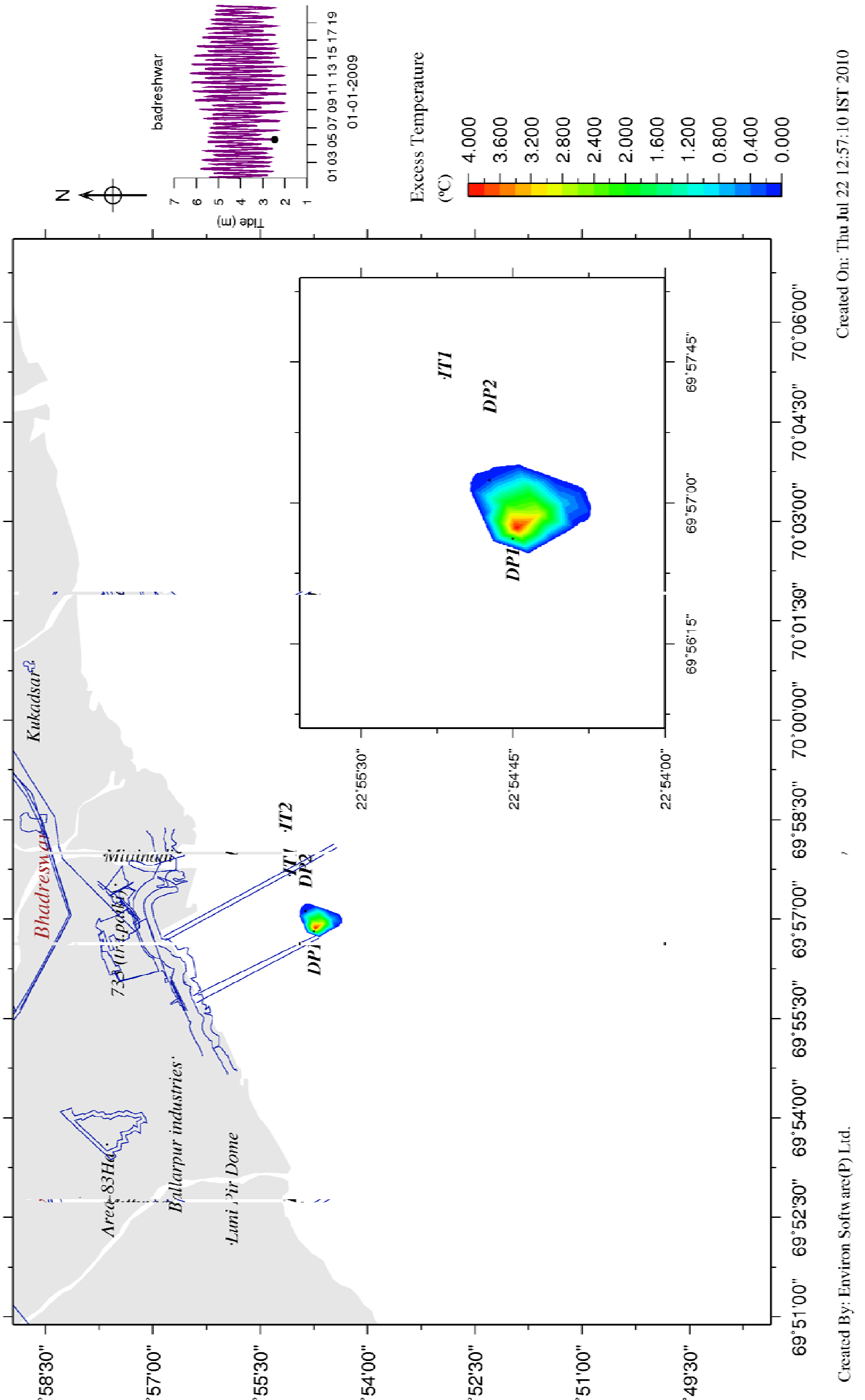


Fig. 16 Variation of temperature during LW of neap tide (DP1)

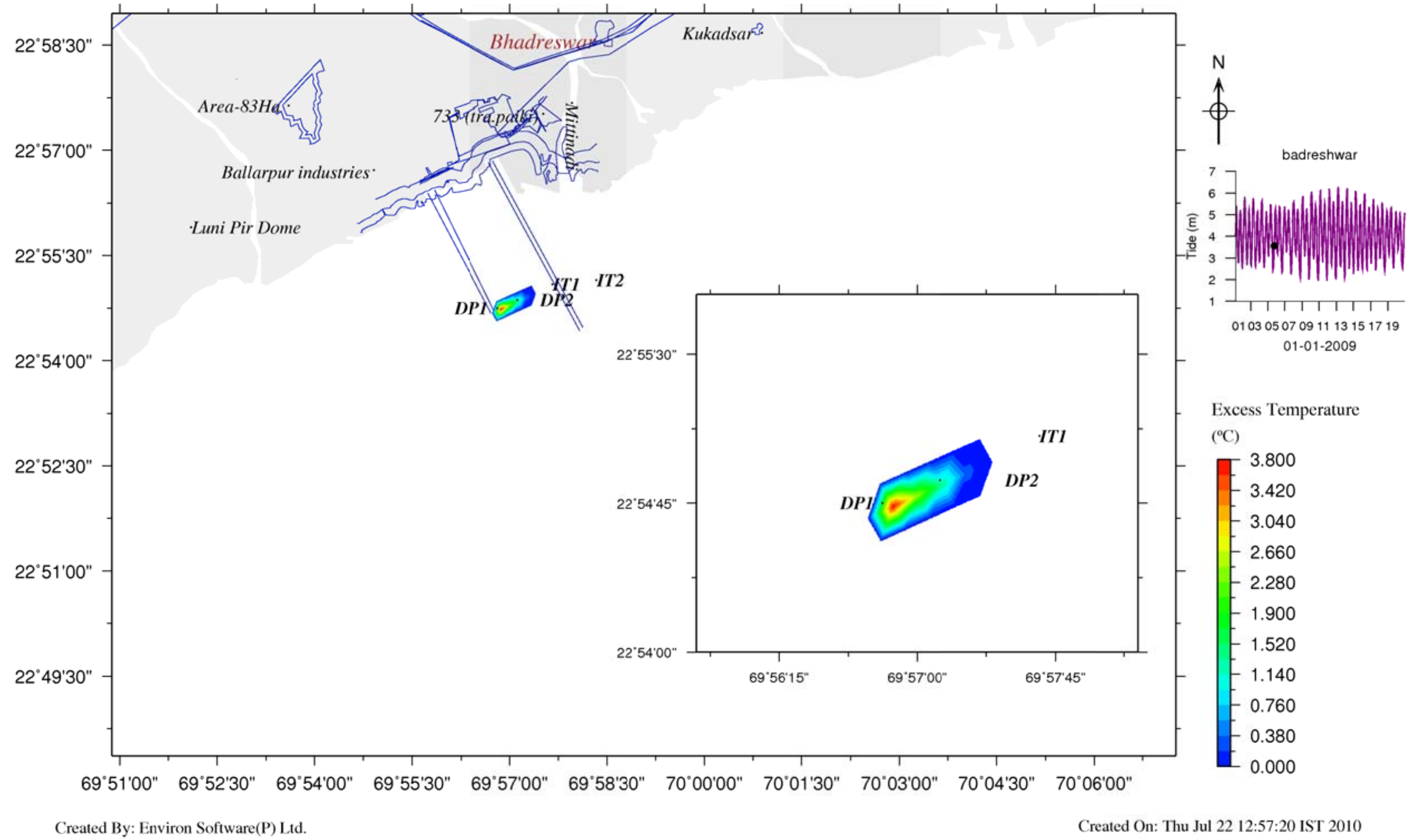


Fig. 17 Variation of temperature during peak flood of neap tide (DP1)